

Method and device for determining characteristics of molten metal

The invention relates, on the one hand, to a method for determining at least one characteristic of a molten metal, by means of a measuring device for generating measurement data of these characteristics, and a processing device arranged outside of the molten metal, for processing these measurement data, whereby the measuring device is introduced into the molten metal; on the other hand, to a device for implementing this method; and finally, to a related measuring device.

Methods of this type, using such measuring devices, are used to determine the current precise values of temperature and oxygen affinity in a converter, for process control during steel production, for example. Alternative methods for determining these characteristics have not been able to achieve any significant importance until now, because of various insufficiencies in their practical use:

- Using methods of numerical process simulation, it is only possible to estimate characteristics of a steel production process at a concrete point in time in

approximate manner. However, the precise knowledge of individual variables is frequently required to control and guide the process.

- Thermoelements, optical or pyrometric measuring devices installed on the converter vessel in fixed manner are proposed by various authors. Such measuring devices are subject to great wear, because of the permanent, very high temperature stress, and because of falling "boiler bears."
- Blowing lances having a built-in pyrometer are used to measure the temperature while blowing, in contact-free manner. However, such measuring devices are not suitable for assessing samples and for measuring the oxygen content.

Fundamentally, methods of this type are known, along with devices for their implementation, which use measuring devices of this type to determine characteristics of a molten metal. In this connection, the measuring devices are either thrown into the molten metal from a drop station, or introduced into the molten metal using a lance. The measuring device is connected with a processing device for processing the measurement data, by way of a cable. Data are processed in the processing device,

for example statistically, they are used to control or regulate the steel production process, fed on-line into a numerical simulation that runs parallel, or displayed in the form of characteristics.

The instruments and components integrated into the immersion body are protected by means of a sheathing made of a heat-insulating material, in such a manner that they remain operable for the duration of the measurement. U.S. 3,374,122 describes an immersion body, for example: It is proposed there, for one thing, to increase the weight of the measuring device, in targeted manner, by means of additional integrated masses, so that the measuring device reliably passes through the slag layer under its own weight; and, for another thing, to equip the measuring device with tines that project downward, in order to prevent damage of the thermoelements, which also project, during the impact onto the slag surface.

A floatable immersion body is described in U.S. 4,881,824: A rod-shaped, elongated probe, particularly for insertion of a sampling body into a molten metal, is made heavier at the bottom end by means of a thickened steel pipe, for one thing; on the other hand, it is surrounded at the top end by a cardboard

sleeve, as a flotation body. In this connection, the weighting and the flotation body are adapted to the known density of the molten metal, and thereby to the known flotation forces, in such a manner that the immersion body passes through a slag layer that is formed on the surface of the molten metal, is immersed to a defined depth with its weighted end, and is held in a vertical position, floating in the molten metal, by means of the flotation body.

The cable of such an immersion body remains connected with the drop station above the converter during the measurement; the data are passed on from the drop station to the processing device for processing the measurement data. Such a drop station is described, for example, by U.S. 5,610,346: Here, in particular, a special coordination of the suspension of several immersion bodies and the attachment of their cables in the drop station, and a device for cutting off the cable ends that remain after every measurement, are proposed. After the measurement, the cable burns off in the converter. In the drop station, the remaining cable end is cut off and drops into the converter, where it also burns off.

Despite such highly developed devices and methods using immersion bodies, the connecting cable to the processing device remains a significant weak point of the system:

- Despite heat protection mantling, U.S. 5,584,578, for example, proceeds from the assumption of a useful lifetime of the cable, and therefore a useful lifetime of the measuring device, of not more than 16 seconds.
- The cable end that remains in the drop station must be reliably cut off after the measurement and, in particular, removed from the drop path, since otherwise it can block the subsequent immersion body. When using a feed device as the ejection path, this device as a whole can be blocked.
- Magazining of several immersion bodies in the drop station, in order to reduce the operating effort, requires complicated coordination of the drop mechanism as well as the circuitry of the individual connections.

It is furthermore generally known to introduce a measuring device, a so-called "measuring head" on the tip of a lance, into the molten metal manually, from the casting stage. In this

connection, the measuring head and the lance end are surrounded by a cardboard sheath, which protects the two components from the heat of the molten metal and from splashing metal. Like the immersion bodies already presented, here again the measuring head is generally destroyed by the measurement, and is disposed of, together with the cardboard sheath, after one-time use. The manual introduction of a measuring head by means of a lance does represent a very simple method of this type, but has a number of decisive disadvantages, particularly in mass production:

- The accuracy of the measurement is significantly dependent on the level of training of the operator.
- When dipping the lance into the molten metal, splashing metal that exits endangers the health of the operator.
- The converter process must be interrupted for the time of the measurement, in order to be able to move the converter into a position at an incline to the casting stage.

These disadvantages of the manual use of lances equipped with measuring heads are eliminated by the use, which is also known, of sub-lances that can be automatically introduced along with

the blowing lance and removed again. However, the effort and expense of design, installation, and maintenance of the machine equipment required for this is disproportionately high.

The Japanese patent application JP 2000028438 describes a device for measuring temperature, specific concentrations, and other physical characteristics of a melt at elevated temperature. This device has a so-called sub-lance, at the tip of which an interchangeable measuring head is arranged, which is moved into the melt by means of a corresponding movement of the lance. A transmitter in the measuring head converts sensor signals into a high-frequency signal, which is passed along by way of cables and a plug connection between the measuring head and the metallic sub-lance. In this connection, the sub-lance is used to pass on the high-frequency signal and as an antenna, in order to transmit the signals to a receiver outside the vessel for the melt, in wireless manner.

By means of the conversion of several sensor signals into one high-frequency signal, the multi-pole plug that is otherwise needed between the measuring head and the sub-lance is greatly simplified, and its contamination by means of tar-containing residues of the fireproof lining of the metallurgical vessel in

which the device is being operated no longer has such a great effect.

However, it is a disadvantage in this connection that this device requires a lance, for one thing, and a plug connector between the measuring head and the lance, for another thing. This is because the majority of metallurgical vessels, such as converters, on which this device is supposed to be used, do not have such lances. The expense and effort for the installation and maintenance of such a lance are very great. The electrical contact at the lance tip required for coupling the high-frequency signal from the measuring head to the lance is furthermore susceptible to contamination or destruction, and must be cleaned, tested and, if necessary, replaced, by means of corresponding devices.

Task

It is the task of the invention to propose, on the one hand, a method and, on the other hand, a device for its implementation, which allow the determination of characteristics with clearly reduced effort and expense in terms of apparatus, control technology, and organization, while at the same time achieving

increased reliability as compared with the state of the art. Thus, implementation of the measurement is supposed to be facilitated in general, but particularly with regard to its automation.

Solution

Proceeding from the methods described initially, this task is accomplished, according to the invention, in that the measuring data are transmitted directly from the measuring device to the processing device, in wireless manner. By means of this measure, the disadvantages of the known methods, which are inseparably related to the cable, are eliminated, along with the cable.

- The useful lifetime of the measuring device is no longer limited to the survival period of the cable in the molten metal. In this manner, more complicated measuring methods, for example multi-stage measuring methods, can be carried out by a measuring device.
- When using immersion bodies, no cable end remains in the drop station. The complicated apparatuses and arrangements for cutting of this cable end and reliably removing it from the drop path are eliminated,

as is the remaining risk of blockage of the drop path by a cable end that has not been completely removed.

- A physical connection with the measuring device is no longer required. When using lances, coupling the cable end to the processing device, which is a source of errors, becomes superfluous. When magazining immersion bodies in a drop station, a separate connection no longer has to be provided for each individual immersion body.
- Automation of the method is facilitated, particularly when using immersion bodies. Filling a magazine is simplified and significantly accelerated, since no cables have to be plugged in; because the cables are eliminated, a larger number of immersion bodies can be accommodated in the same space. In operation, the work step of "cutting off the cable end" and monitoring of its successful completion are eliminated.

In this connection, the processing device according to the invention comprises a reception device, e.g. a reception antenna, which can be placed at a distance of several 100 m ahead of the remaining processing device, e.g. in the form of a computer with the usual peripherals, such as a monitor, keyboard, printer, etc.

While the reception device should generally be located not too far removed from the molten metal, for reasons of transmission reliability, it is recommended to arrange the remainder of the processing device well protected, at a sufficient distance from the molten metal. The transmission from the reception device to the computer will generally take place via a cable. The measuring device according to the invention comprises an integrated transmission device with which the emission of signals containing the measurement values to be transmitted is possible.

Another significant advantage of the method according to the invention is to be seen in that it is possible to do without the use of a lance entirely, so that the method can be utilized in combination with almost all metallurgical vessels, in cost-effective manner. As compared with the method of procedure shown in JP 2000028438, the invention is characterized by the elimination of all plug connections in the region of the measuring device, since the latter have very frequently proven to be the weak point of existing devices in the past, because of the extreme conditions in operation.

It is preferred to structure the method according to the invention in such a manner that the measuring device is introduced into the molten metal from a drop station, taking advantage of gravity. Implementing the measurement is then possible without interrupting the converter process.

In industrial use, e.g. in steel production, the implementation of the method according to the invention is preferably automated, in the form of a measuring cycle consisting of initialization, selection and preparation of a measuring device, introduction of the measuring device into the molten metal, recording and transmission of the data, and completion of the measurement. A measurement cycle can be triggered by means of a regular time pulse, or as a function of measured or calculated characteristics of the process.

Transmission of the measurement data from the measuring device preferably takes place in the frequency range of the ISM bands (ISM = Industrial Scientific Medical) according to IEEE 802.11, particularly at 2.4 GHz or at 433 MHz. Fundamentally, other frequency ranges can also be used, as long as they are sufficiently suitable for transmitting measurement data from the measuring device to the processing device during the measurement.

Proceeding from the devices for determining characteristics of molten metal, of the type as described, the task of the invention is furthermore accomplished in that in the case of such a device, the measurement data can be transmitted directly from the measuring device to the processing device, in wireless manner. The latter device also has the advantages described above, which result from the elimination of the transmission cable as well as any plug connections to a lance. The device according to the invention can be constructed in clearly simpler and therefore more cost-effective manner, because of the elimination of the cable connection devices and cable cutting devices, as compared with the known devices. With the reduced number of modules, the space requirement for the device according to the invention is also reduced, as is the maintenance and monitoring effort and expense in operation. In total, the device according to the invention significantly facilitates automated measurements of characteristics of molten metal.

The device according to the invention can be used to measure physical or chemical characteristics in or on the molten metal. In particular, thermoelements for measuring the temperature, EMK

measurement probes for measuring oxygen, sensors for determining the fill level and slag thickness, as well as combinations of the stated sensor elements can be used. The data determined can be transmitted either directly as analog data, or after A/D conversion. In the case of measurements in molten metal with a slag layer that has formed, it proves to be practical to protect sensitive sensor elements at the bottom end of the measuring device by means of metallized ribs or projecting tines, against damage caused by impact on the slag surface.

The measuring device of the device according to the invention can have an integrated sensor element that projects out of the molten metal during the measurement. This makes it possible to transmit the measurement data, without interference, to a receiver arranged above the molten metal, preferably at a protected location on the exhaust device or on the feed chute. To protect it from excessive heat radiation, the reception antenna can be configured in such a manner that it is automatically covered or retracted during the pauses between measurements. Interference-free transmission is further promoted if the transmission element, which is configured as an antenna, for example, is protected against splashed metal, to a great extent, by means of a cardboard sheath or a ceramic

coating. The projecting transmission element can furthermore be configured as a holder element of an immersion body in a drop device.

In order for the measuring device to demonstrate sufficient transmission power, it can furthermore have an energy storage element, particularly batteries or high-power capacitors, which are connected with the sensor electronics, or charged, immediately before the start of the measurement.

The device according to the invention can be configured in particularly simple manner in that the measuring device can be manually introduced into the molten metal. Preferably, however, the device according to the invention is configured in such a manner that the measuring device can be introduced into the molten metal from a drop station, taking advantage of gravity. This makes it possible to perform the measurement without interrupting the converter process. The dimensions, particularly the length and weight of such an immersion body, result from the intended immersion depth into the molten metal and from the required protection of the antenna, in terms of design. Fundamentally, slim construction shapes, in other words

immersion bodies with the smallest possible diameter, have proven themselves to be advantageous.

In industrial use, the drop station of a device according to the invention is preferably configured as a magazine that can hold several measuring devices. Magazining of measuring devices makes it particularly possible to trigger measurement cycles automatically, as described above, without any manual intervention in the device.

The device according to the invention preferably transmits the measurement data determined by it in the frequency range of the ISM bands (as already explained above).

The method and the device according to the invention can fundamentally be used not only in molten metal, but also in other melt baths, for example in molten glass.

The invention also comprises the measuring device for introduction into a melt bath at elevated temperature, considered by itself.

Exemplary Embodiment

In the following, the invention will be explained using an exemplary embodiment, which is shown in figures. These show:

Fig. 1 a converter system with a device according to the invention, for determining characteristics of a molten metal,

Fig. 2 an immersion body of this device, and

Fig. 3 the drop station of this device.

The figures show a converter system 1 having a converter 2 and a device 3 for determining characteristics of a molten metal 4 of an alloy steel that is not described in detail. The converter 2, which is actually known, contains the molten metal 4 and is domed by an exhaust device 5. The device 3 for determining characteristics essentially consists of a drop station 6 having a plurality of measuring devices 8 accommodated in it, and a processing device 7, also previously known, for controlling the drop station 6 and for displaying and processing the characteristics that are determined.

The measuring device 8 is an immersion body having a known, elongated shape. At its bottom end 9, it has sensors 10 that transmit analog measurement values of characteristics to a device 11 for signal processing. From there, these measurement values are digitalized by way of an A/D converter 12, and passed on to a transmitter 13, which emits them by way of a transmission antenna 14 at the top end 15, into the surroundings. The electrical and electronic components 11, 12, 13, and 14 in the measuring device 8 are supplied with energy for the time period of the measurement, by way of a capacitor 16. The sensors 10, the device 11 for signal processing, the A/D converter 12, the transmitter 13, and the transmission antenna 14, as well as the capacitor 16, are known and therefore shown only schematically.

Similar to the arrangement described in U.S. 4,881,824, the measuring device 8 is provided with a weight made of a material having a suitable density, for example steel or lead, at the bottom end 9, in a manner not shown. In this manner, the bottom end 9 of the measuring device 8 has a higher density than the molten metal 4, particularly, in the case of molten steel, a density greater than 7.2 g/cm^3 . The rod-shaped, elongated flotation body 17 is made from a material of lesser density, for

example from a cardboard tube bound with silicate. The dimensions of the flotation body 17 are selected in such a manner that the electrical and electronic components 11, 12, 13, 14, and 16 can be accommodated in its interior, on the one hand, and that a protective, heat-insulating sheath that is sufficient for these components is guaranteed by the wall thickness selected, on the other hand. Typically, the wall thickness of the flotation body 17 is greater than 7 mm. The top end 15 of the measuring device 8 is provided with a coating 18 of fireproof ceramic or of cardboard, so that the transmission antenna 14 that projects out of the flotation body 17 is protected against damage from splashing metal or slag particles when the measuring device 8 is immersed into the molten metal 4 and during the measurement. The drop station 6 is arranged on the side, above the exhaust device 5, and in this way protected, to a great extent, from the heat radiation that proceeds from the converter 2. The drop station 6 has essentially a high box shape, open towards the top, having an elongated base surface. Its bottom 19 is inclined relative to a pipe 20 that is affixed on the side, below the drop station 6. The face 21 has a flap 22 that can be opened electrically, ahead of the pipe 20, and an ejection device 24, which is also operated electrically, on the opposite back wall 23. In the bottom 19 of the drop station 6,

a charging station 25 is arranged directly ahead of the flap 22; the transmission coil of this station, not shown, charges the capacitor 16 by way of a reception coil, not shown, in the measuring device 8. Approximately ten measuring devices 8 are magazined in the drop station 6, lying loosely above one another. The flap 22, which is closed during operation, protects the measuring device 8 lying in the drop station 6, particularly against darting flames and radiation heat from the converter 2.

A reception antenna 26 is also arranged above the exhaust device 5; data transmitted from the region of the molten metal 4 can be recorded and transmitted to the computer 7 by means of this antenna.

To determine characteristics of the molten metal 4, the flap 20 on the drop station 6 is opened by means of a pulse generated in the computer 7, and the bottommost measuring device 8 is transported into the pipe 20 by means of the ejection device 24. In the drop station 6, the next measuring device 8 slips into the bottommost position. By means of positioning this measuring device 8 in the vicinity of the charging station 25, the

capacitor 16 of this measuring device 8 is charged, and the measuring device 8 is thereby activated for its subsequent use.

The measuring device 8 transported into the pipe 20 is guided through the exhaust device 5 and falls down into the converter 2, penetrates the slag layer 27 on the surface 28 of the molten metal 4, and gets into the molten metal 4.

The measuring device 8 passes through the slag layer 27, because of its weight, and reaches the molten metal 4. The density within the measuring device 8 is distributed in such a manner that the measuring device 8 floats upright in the molten metal 4, whereby on the one hand, the sensors 10 get to the desired depth in the molten metal 4 and record its characteristics and, on the other hand, the transmission antenna 14 projects at least 0.3 m upward above the slag layer 27. The transmitter 13 transmits the measured characteristics by means of the transmission antenna 14 that projects out of the molten metal 4, up to destruction of the measuring device 8, to the reception antenna 26, from which they are transmitted to an evaluation device located in the computer 7, by way of a reception device, not shown in detail, and presented and processed further there.